

Extruder Barrel Alignment Today

By: Richard Henry
Alignment Specialist
The ADVANCED Team

Extruder barrel alignment is one of the most important aspects of a properly and efficiently operating plastics extrusion process. Whether it's a blown film line, injection molding or extruded sheet process, the relationship between the rotational center of the thrust shaft in the gearbox and the rotational center of the screw are vital.



Misalignment is known to cause excessive screw wear and barrel wear. If the misalignment is severe enough, the screw can fail prematurely as a result of the fatigue caused by the cyclic bending of the screw as it rotates in the barrel. In some cases, the clearance that is opened up between the flights of the screw and the barrel will allow significant losses of system efficiency and through-put of the system.

We believe it is a fair statement that the real value of a plastics extruding line does not rest in any single component of the extrusion process. Rather, the **operation and production** of the system is the value of the extrusion process. If the process isn't operational, for a day, a shift, or even an hour; the company is going to lose production value.

These days, facilities are demanding more and more production from existing equipment. If a poorly aligned extruder system would operate for 5,000 hours prior to failure it would run and be productive for 625 shifts (8 hr/day - 5 days/week) or about 2.4 years prior to a component failure. Honestly, there aren't many production facilities operating at those slow production rates. Most facilities I've visited are working at least 2 shifts/day – 6 days/week. With that same 5000 hour Mean Time Between Failure (MTBF), that same system will only

operate 1 year prior to a failure that shuts down the process and halts production. Not only are the production revenues lost for the period of time it takes to repair the system, the cost of a screw can be \$30,000 or more (depending on size and application) with thousands more spent on labor. Should a failure occur in the feed section of the extruder, an even greater expense can be incurred by having to replace the feed throat. Catastrophic failures can even cause component failures in the drive components (gearbox).

Alignment of an extruder system can be completed in less than 8 hours and typically in less than 4 hours. That 4 hour "investment" will; in all likelihood, result in extending the life of the extruder barrel and screw and keep your facility doing what it is supposed to do:

Making product and moving it out the door.

When operating a misaligned extruder system, wear between the screw and the barrel is going to occur that will open up the design clearance and affect the output of the process. These effects can be incredibly costly to the production of the facility. Here are some basic production loss numbers as they apply to screw/barrel wear.

According to a major US Manufacturer of Barrels and Screws, the effects of diametrical wear of .025"-.030" could result in a 60 lb/hr output reduction.

Here is a typical production loss example using a 4.5" diameter x 24:1 Barrier Screw processing polyolefin.

If:

- Nominal Rate: 1,440 lbs/hr
- Melt Temperature: 430 to 450° F.
- Output Stability: +/- 10%

The wear penalty cost can be calculated as:

$$\begin{aligned} 60 \text{ lbs/hour} \times 0.65 &= \$ 65.00 \text{ /hour} \times 24 \text{ hours} = \$936.00 \text{ per day} \\ &\text{or} \\ &\$28,080 \text{ per month} \\ &\text{or} \\ &\$341,640 \text{ per year} \end{aligned}$$

How long until you notice the decrease in production? Are losses of half that amount small enough that the problem will continue unnoticed?

These numbers get very big very fast. Proper alignment at the time of installation can minimize the wear associated with an extruding process and help keep those losses from occurring in the first place.

I guess that goes back to Benjamin Franklin who said, "An ounce of prevention is worth a pound of cure". Who knew he was talking about plastics extrusion?

Definition of Extruder Barrel Alignment: Positioning the extruder barrel at the supports and the feed throat in such a manner that the barrel mechanical center is concentric with the gearbox thrust shaft rotational center (within a set of tolerances) under normal operating conditions.

That's a pretty big statement and it's not always easy to accomplish.

Alignment Methods

Historically, there have been three methods utilized to align the extruder barrel to the gearbox thrust shaft.

A Level

The first is to measure everything with a level. The idea being that if the machine is level, everything should be aligned. This is a serious misconception and will almost certainly result in a misaligned process and certain failure. This method of extruder barrel alignment does not take into consideration the horizontal position of the barrel. Misalignment in the horizontal plane is just as big of a problem as misalignment in the vertical plane.

Other problems arise when the level used is not a precision measurement machinist level.

The resolution and accuracy of a carpenters level or torpedo level is far inferior and will not give the desired results.

A Borescope

Another alignment method is to use an optical Borescope. A precision bore mounted telescope is installed in the gearbox thrust shaft and "bucked-in" to the mechanical center of the through hole. The eyepiece of the bore scope has a precision cross hair that is focused to infinity. The operator can then site down the barrel and measure the displacement of the optical target at multiple points along the barrel ID, provided the section is accessible and clean.

The accuracy of the optical bore scope is sometimes less than desirable and can cause an apparent "accurate" alignment to fall well outside the prescribed alignment tolerances.



Typical Optical Borescope for Extruder Alignment

A Laser-based Extruder Barrel Alignment System

There are several laser manufacturing companies offering off the shelf extruder alignment systems. A laser system improves accuracy, speed of measurement and reporting on the alignment of the barrel to the thrust shaft rotational center. The typical accuracy of the laser system is approximately 0.001". While the laser system is going to improve the accuracy of the alignment, the money spent on the laser alignment system and the time involved in learning how to properly utilize the technology can sometimes be daunting for a maintenance department.

Simply purchasing a laser system does not qualify someone to perform precision alignment; any more than buying a stethoscope makes someone a medical doctor.

Let's discuss the operation of a laser based extruder barrel alignment system.

Rather than ambient light traveling up the barrel to the operator's eye looking through the Borescope eye piece; a laser system utilizes a columnated beam of laser light directed from a transmitter that is mounted on the thrust shaft. The laser transmitter can be quickly qualified to project the true rotational center of the thrust shaft at any point along the barrel (or even beyond the end of the barrel if mold position measurements are needed). The qualified laser beam strikes the surface of a Position Sensitive Detector (PSD) mounted in the barrel. Rather than a cross hair and scale to measure displacement, the PSD very accurately measures the center of the laser beam to less than half a micron (0.0005 mm) and displays the measurement value on a display unit.

When the laser transmitter is properly qualified to project the rotational center of the thrust shaft to the point of measurement, the results are geometrically infallible.

Depending on the operator and machine configuration, laser based barrel alignment measurements can be completed about 30 minutes with alignment data documented at each barrel support and at the feed throat, provided they are accessible. Corrections are made using live values that are updated in real time in both the horizontal and vertical plane, cutting the correction time significantly.

Establishing Alignment Reference

You have to be very careful about the reference utilized when aligning extruder barrels. If the bore of the thrust shaft is to be used as the reference, it has to be unquestionably accurate. That means the bore of the thrust shaft needs to be precisely concentric at both ends with the rotational center of thrust shaft. Any deviation (as small as 0.002") will lead to misalignment of the barrel. In some cases, it can lead to severe misalignment. By severe, I mean misalignment in excess of 0.250" or greater at the die end of the barrel.

I have witnessed visible amounts of run-out in the thrust shaft bore. If the run-out is visible to the naked eye, it is in excess of 0.020". Let's consider the math. 0.020" doesn't really sound that bad, does it?

It's not the 0.020" of run-out alone that is the problem. It's the run-out divided by the length of the thrust shaft that produces the error in the reference, and therefore the catastrophic error in the alignment at the die end of the barrel.

Let's consider the above run-out and assume for a minute that it is 0.020". The thrust shaft on this machine was 30" long. That puts an angular error in the measurement of 0.00066" per inch of barrel length. This was a 7" diameter barrel with a typical 24:1 Length : diameter ratio. $7" \times 24 = 168"$ barrel length.

$168" \text{ barrel} \times 0.00066"/" \text{ angular error} = 0.110"$ error in the measurement if the thrust shaft bore is used as a reference for the alignment. This means that the Borescope operator will be reading close to zero, when in fact that position is almost 1/8" out of alignment to the rotational center of the gearbox output shaft. This is precisely why the rotational center of the thrust shaft, rather than the mechanical center, needs to be used as a reference to align extruder barrels.

If the above example was a 40:1 Extruder Barrel, the misalignment would be 0.180". Let's assume that for these two examples the run-out was only .002". The misalignment caused by the two thousandths of an inch difference would equate to 0.011" for the 24:1 and 0.18" for the 40:1. Even at .002" of run-out, the misalignment created by the deviation of the reference of choice is greater than our allowable alignment tolerances.

Tolerances

Alignment tolerances are also a point of contention as they apply to extruder barrels and screws. A typical screw/barrel clearance rule of thumb is as follows:

Radial Clearance = Nominal Diameter x 0.001"

Nominal Diameter	Specified Barrel I.D. Size	Specified Screw O.D. Size	Barrel/ Screw Diametrical Clearance
2"	2.000 +.001/- .000	1.996/1.995	.004/.005
2-1/4"	2.250 +.001/- .000	2.246/2.245	.004/.005
2-1/2"	2.500 +.001/- .000	2.495/2.494	.005/.007
2-3/4"	2.750 +.001/- .000	2.745/2.744	.005/.007
3"	3.000 +.001/- .000	2.994/2.993	.006/.008
3-1/4"	3.250 +.002/- .000	3.2435/3.2425	.0065/.0095
3-1/2"	3.500 +.002/- .000	3.493/3.492	.007/.010
3-3/4"	3.750 +.002/- .000	3.743/3.742	.007/.010
4"	4.000 +.002/- .000	3.992/3.991	.008/.011
4-1/4"	4.250 +.002/- .000	4.242/4.241	.008/.011
4-1/2"	4.500 +.002/- .000	4.491/4.490	.009/.012
4-3/4"	4.750 +.002/- .000	4.741/4.740	.009/.012
5-1/4"	5.250 +.002/- .000	5.240/5.238	.010/.014
6"	6.000 +.002/- .000	5.988/5.986	.012/.016
8"	8.000 +.002/- .000	7.984/7.982	.016/.021

The right column (in red) indicates the clearance between a new barrel and a new screw "as new". A typical 4" diameter barrel has only 0.008" of diametrical clearance or 0.004" of radial clearance. Misalignment greater than that WILL cause barrel and screw wear.

*****Should we discuss "our" alignment tolerances/targets?*****

Twin Screw Extruders

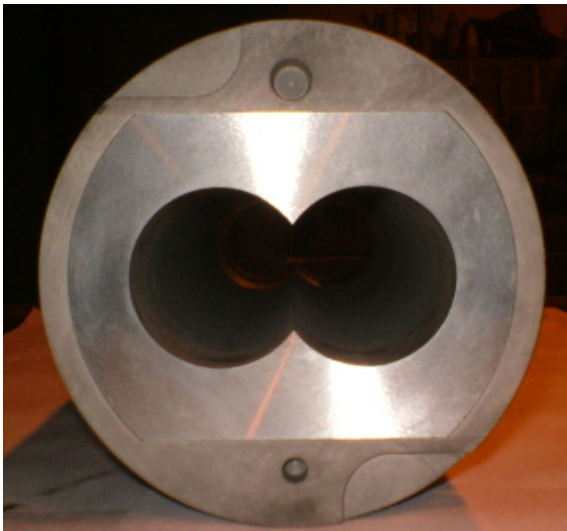
A twin screw extruder barrel has the same alignment tolerances as a single screw barrel. Although the measurement procedure is slightly different from a single screw application, the overall measurement goal is exactly the same; to eliminate the unnecessary wear and fatigue failures do to barrel misalignment.

The laser measurement procedure is much better suited to complete this type of barrel alignment. Typically, there is not a thrust shaft with a line of sight hole to allow a Borescope to be mounted. A laser transmitter can be mounted on the gearbox output shaft quite easily and the alignment of barrel can then be measured in the same manner as a single screw extruder.

We recently performed an alignment on a 23mm twin screw extruder in Michigan. This extruder had a history of failing screws in less than 30 days. Typically, the screw would shear at the coupling end between the barrel and the gearbox. This is the thinnest section of the screw.

We found the barrel out of position at the die end by 0.065" in the horizontal plane and 0.019" too high, relative to the rotational center of the gearbox output shaft. Adjustments were made to the die end of the barrel in both the horizontal and vertical planes.

The extruder has been operating without failure for a year now.



4 hours invested in precision alignment has saved this company tens of thousands of dollars in screws as well as added about 12 more days of production to the bottom line!

Barrel/Screw Diameter vs. The Need for Precision Alignment

I've heard numerous times extruders that are smaller than about 3" in diameter don't require precision alignment. We have also heard that the shorter barrels of injection mold machines do not need alignment. I know we are a little biased, but I could not disagree more with that statement.

Referring to the clearance chart above, it's pretty clear to me that the need for precision alignment is just as important on smaller diameter barrels as it is on large diameter barrels.

It's our position that the reason this idea is believed is that there aren't many alignment systems; or alignment specialists, for that matter, that can handle measuring a bore that small. Still another reason I've heard is that *"the screw is flexible enough that alignment doesn't have to be considered"*.

Again, I would argue that a given amount of misalignment, and therefore cyclic fatigue stresses on a 1" diameter screw will cause a failure exactly as it would on a 4" screw. The technology is available and readily adaptable for the measurement of just about any extruder system in use.

Some relatively straight forward engineering analysis provides us with an approximation of some of the forces applied to the barrel and screw when 0.060" of misalignment is present at the die end of the barrel.

A 1.5" 24:1 screw will require approximately 450 lbs of force to bend it 0.060".

For a 4" 24:1 screw, this number sky rockets to approximately 9,500 lbs or force.

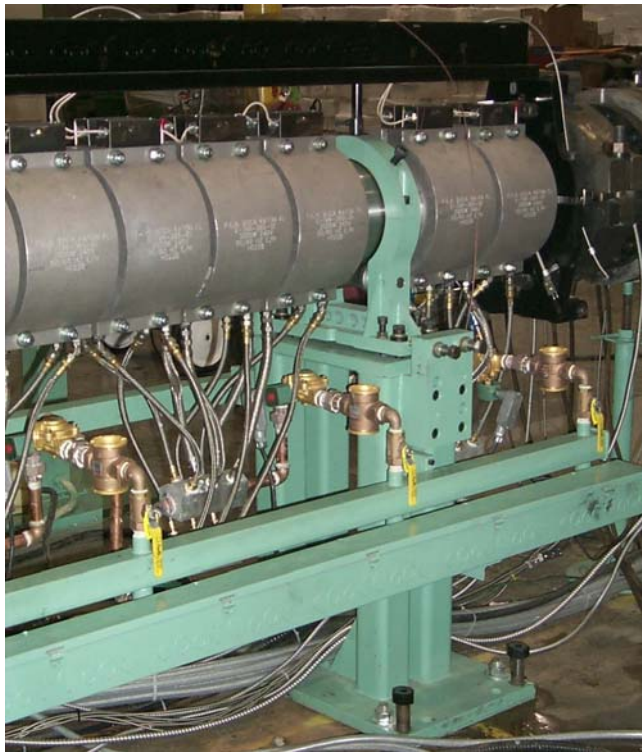
The force value for a 1.5" diameter screw is compelling on its own. That would be the equivalent of operating the extruder with a motor cycle suspended from its mid-point.

Extruder Barrel Supports

The support structure under the extruder barrel is of critical importance to the life of the extruder barrel/screw system and the quality of the alignment as the machine reaches normal operating temperatures. Most extruders have one or more mechanical supports under the barrel. They have 3 basic functions:

- Support the barrel to prevent it from sagging due to its weight.
- Act as an axial guide to allow the barrel to expand and grow in length as the system is heated up.
- Most important...to provide a structurally sound method of making precise vertical and horizontal adjustments to properly align the barrel with the thrust shaft rotational center.

All too often, extruder barrel supports do not have mechanism(s) for alignment. This leads to more time and dollars in making the alignment possible. The lack of jacking bolts and/or shims should not be justification for believing that the alignment process is unnecessary.



This is an example of a properly supported and adjustable barrel.

As you can see in the picture above, the barrel is adequately supported, has plenty of clearance to insert shims to perfect the vertical alignment and has horizontal jacking bolts to allow for precision positioning of the barrel in the horizontal plane.

Thermal Growth of the Extruder Barrel

After the alignment, the extruder screw will be inserted in the barrel, the screen changer and mold will be placed back in the system and the system will be placed on line. As the extruder barrel heats up it is going to expand.

If the barrel is supported from below, it will rise in elevation as the barrel temperature reaches a stable operating point. These elevation changes will have an impact on the alignment of the barrel. The thermal growth at the die end of the machine, as well as at any other supports should be measured and accounted for as part of the alignment process.

Our measurements have confirmed a 0.0125" change in the elevation on a 3" diameter barrel when heated up to approximately 600°F. That is a diametrical change. The centerline change in the vertical plane will be exactly half of that value; or 0.00625".

What does this mean? It means that a barrel, aligned to "zero" in the horizontal and vertical planes cold will be misaligned slightly when the process is heated up. Every effort should be made to account for these changes when aligning the barrel in its cold state.

With today's measurement equipment, obtaining the changes in barrel elevation and horizontal position from Off Line and Cold to operational conditions is relatively easy.

Conclusion:

Today's manufacturing environment demands maximum production at minimal cost. Eliminating losses in process streams will help ensure a manufacturing facility maintains its competitive edge and stays profitable for the long term. There aren't many areas in a facility that will exhibit the return on investment faster than properly installing and maintaining production process equipment.

No where is this more important than in the plastics industry, where the "other guy" is always barking at the door.

Modern methodologies and measurement tools stream line installation and maintenance jobs saving time, money and frustration. One of the most expensive phrases I've heard in maintenance is, "That's the way we've always done it."

Properly installed, aligned and maintained extruder processes will continue to pay off huge production dividends long after poorly installed and maintained equipment has failed.

